Evaluation of AIRS, IASI, and OMI Ozone Using in situ Data from START08

Jasna Pittman, Laura Pan (NCAR)
Jennifer Wei, Eric Maddy, Chris Barnet (NOAA)
Bill Irion (JPL)
Xiong Liu (UMB)
Ru-Shan Gao (NOAA)

May 5, 2009

MOTIVATION

- Evaluate tracer measurements from AIRS, IASI, and OMI
  - Plans to have IR measurements for ~20 years
    - Global and long-term studies
  - 4x daily coverage between the 2 IR instruments
  - Check for consistency with OMI, an instrument with well-established data characterization for the total column product
- Use wide horizontal coverage of satellite instruments to provide large-scale context for aircraft measurements

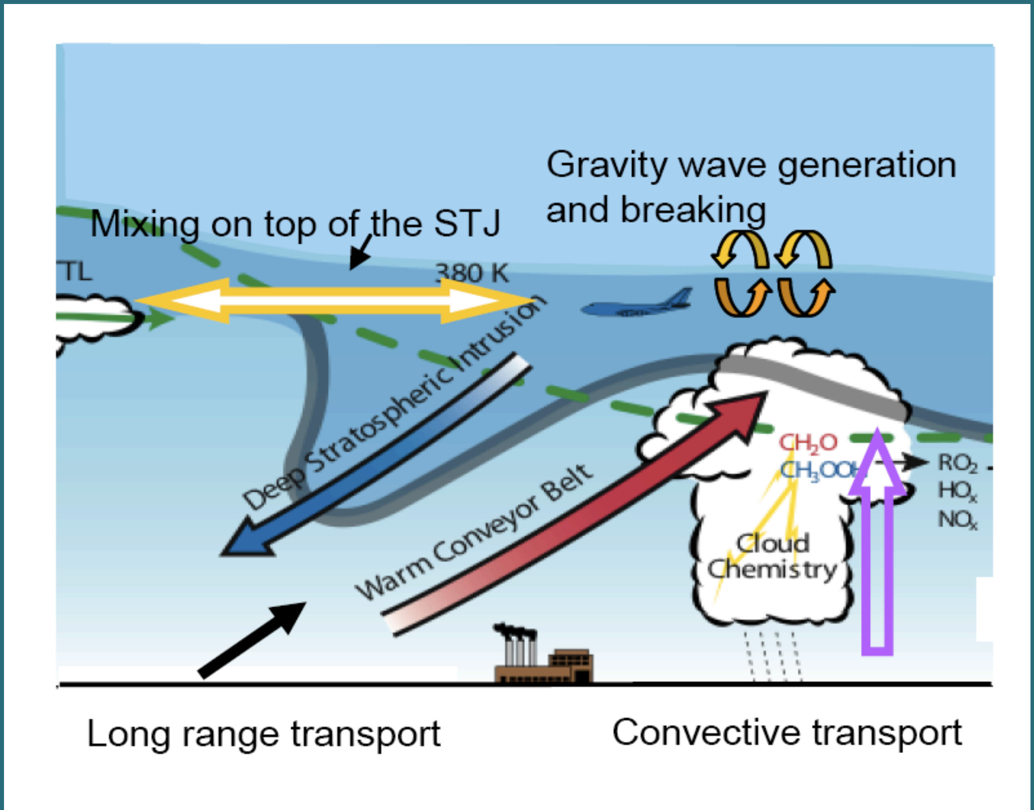
OUTLINE

- Aircraft – AIRS/IASI/OMI Ozone
  - Dynamic variability
  - Horizontal variability
  - Vertical variability

- Aircraft –AIRS/IASI Partial Columns of CO, CH_4 and CO_2

Stratosphere-Troposphere Analysis of Regional Transport Experiment (START08)
and
HIAPER Pole-to-Pole Observations of Atmospheric Tracers (Pre-HIPPO)

April – June, 2008



Science Goals:

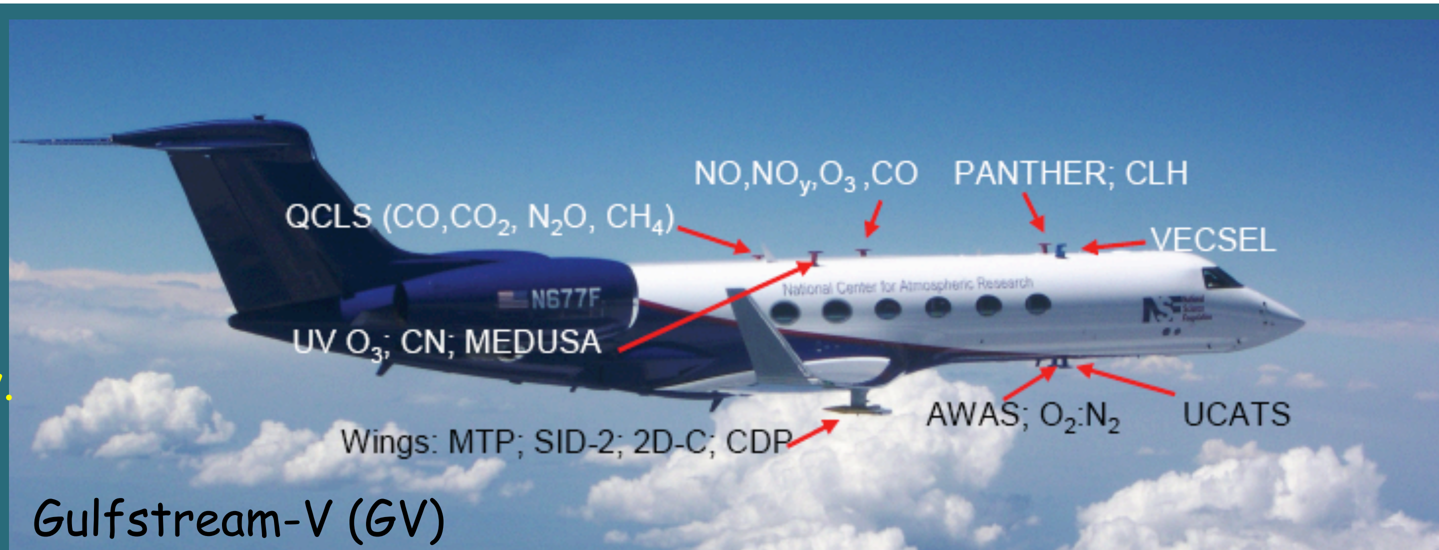
- Characterize the chemical and dynamical properties of the extratropical UT/LS

- Investigate the role of different transport pathways on the distribution of key chemical tracers in the UT/LS region

- Provide key measurement information to improve the coupling between chemistry and dynamics in chemistry-climate models

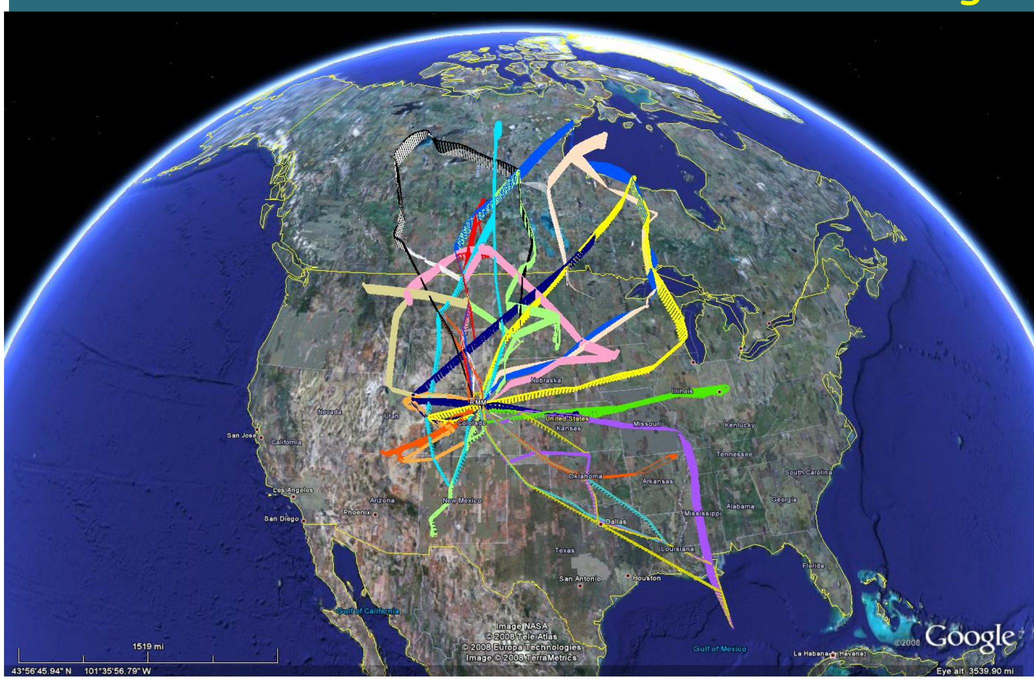
- Map the distribution of greenhouse gases to track seasonal changes in sources and sinks

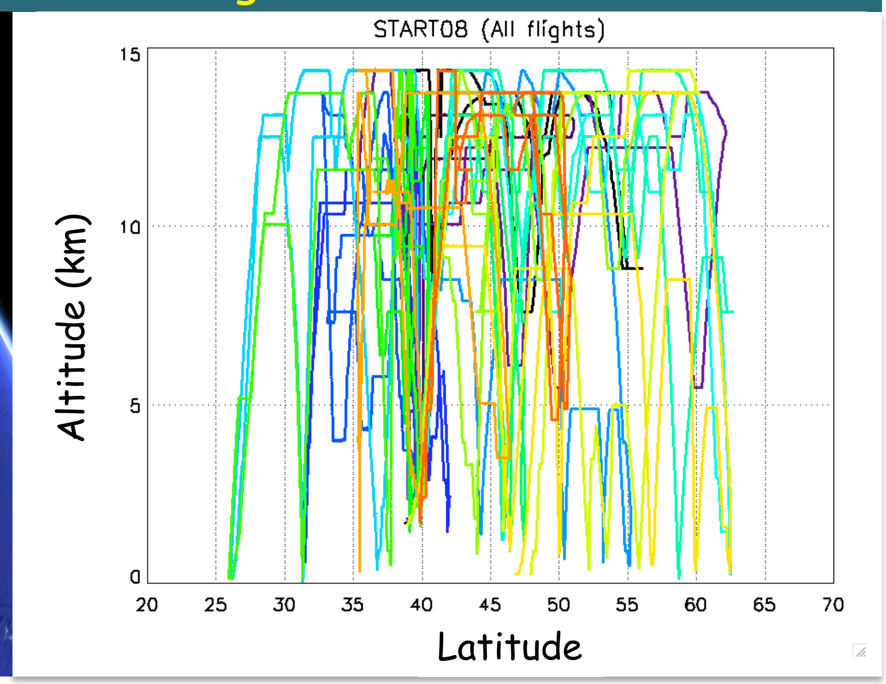
Participants:
- -NCAR
- -NOAA
- -Univ. of CO
- -Harvard Univ.
- -Texas A&M Univ.
- -Univ. of Miami

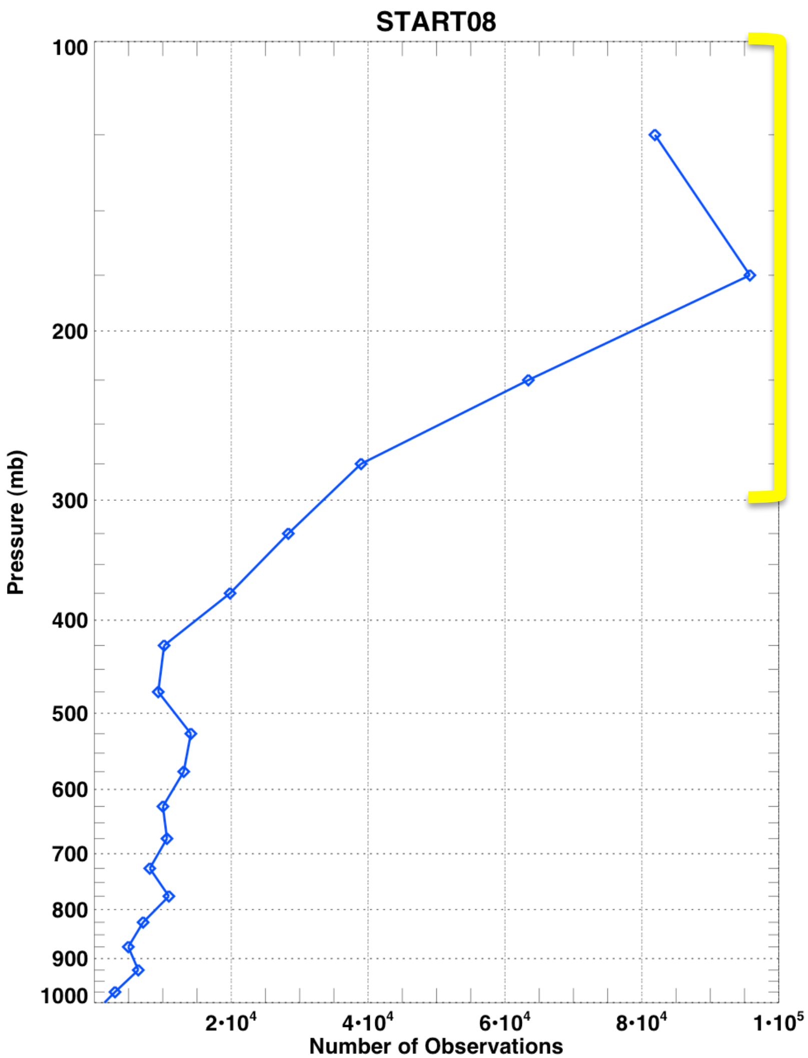


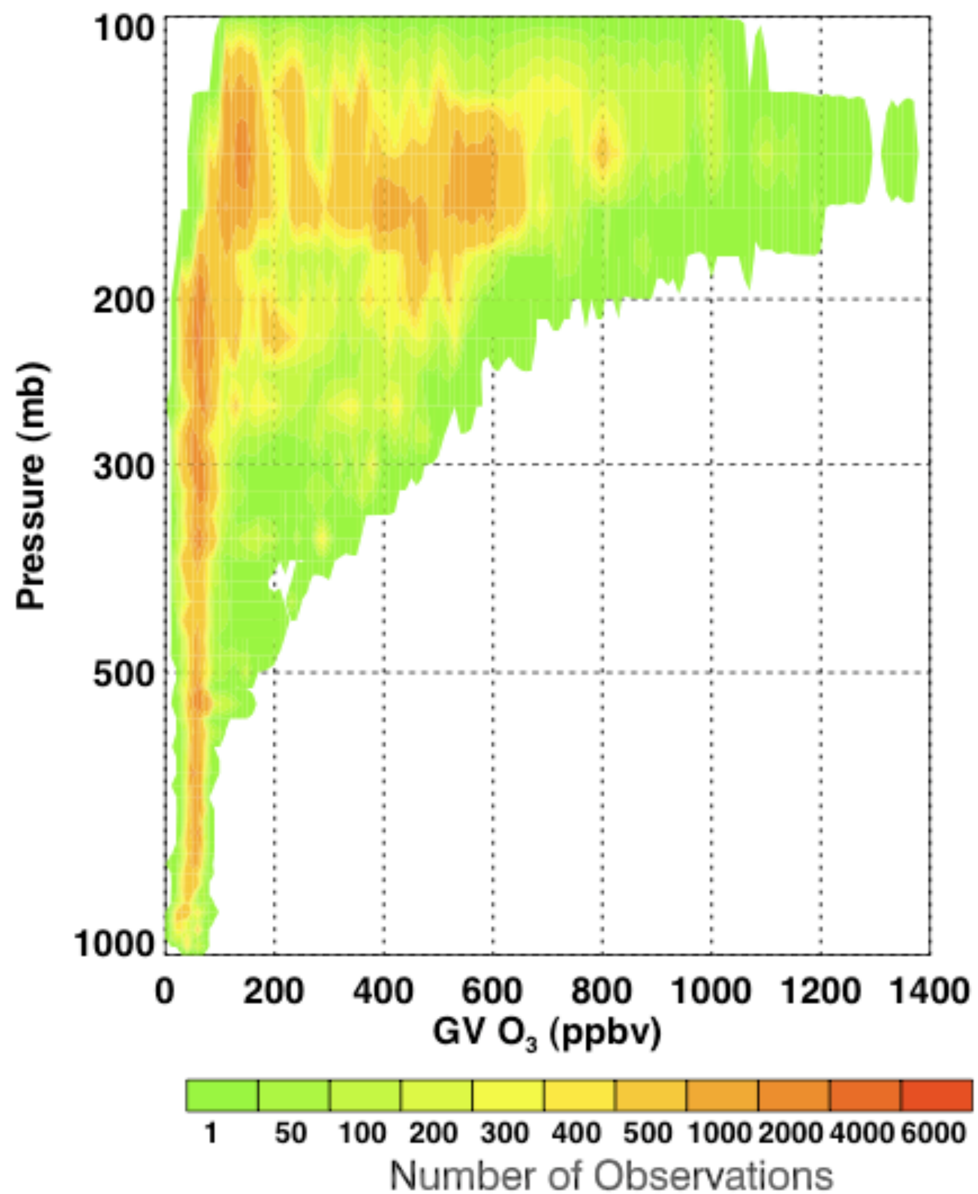
NSF/NCAR High-performance Instrumented Airborne Platform for Environmental Research (HIAPER)

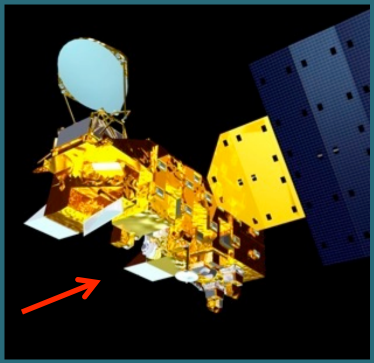
18 Research Flights, 123 Flight Hours





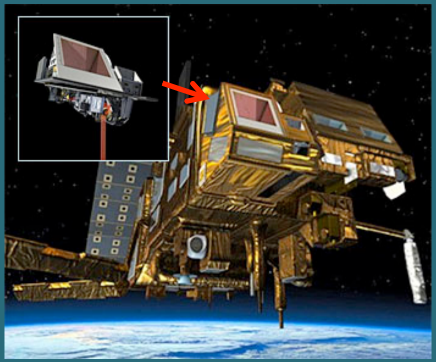

START08
Pressure (mb)
100
200
300
400
500
600
700
800
900
1000
2·10^4
4·10^4
6·10^4
8·10^4
1·10^5
Number of Observations


Pressure (mb)
100
200
300
500
1000
0
200
400
600
800
1000
1200
1400
GV O3 (ppbv)
1
50
100
200
300
400
500
1000
2000
4000
6000
Number of Observations



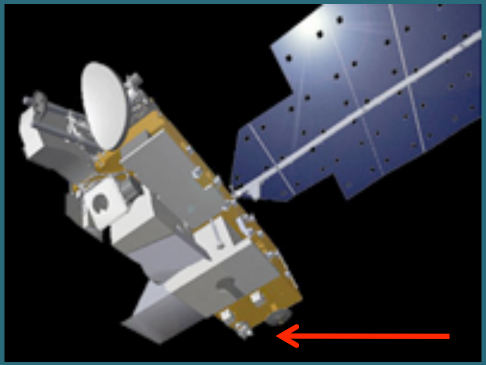
AIRS

- 2,378 spectral bands in the IR (3.7 – 15.4 μm) and 4 in the Visible (0.4 – 1 μm)
- +/- 49.5 ^{o} swath
- 9 FOV, 45 km horizontal resolution at L2
- Launch: May 2002
- PM Equator-crossing
- Aboard Aqua



IASI

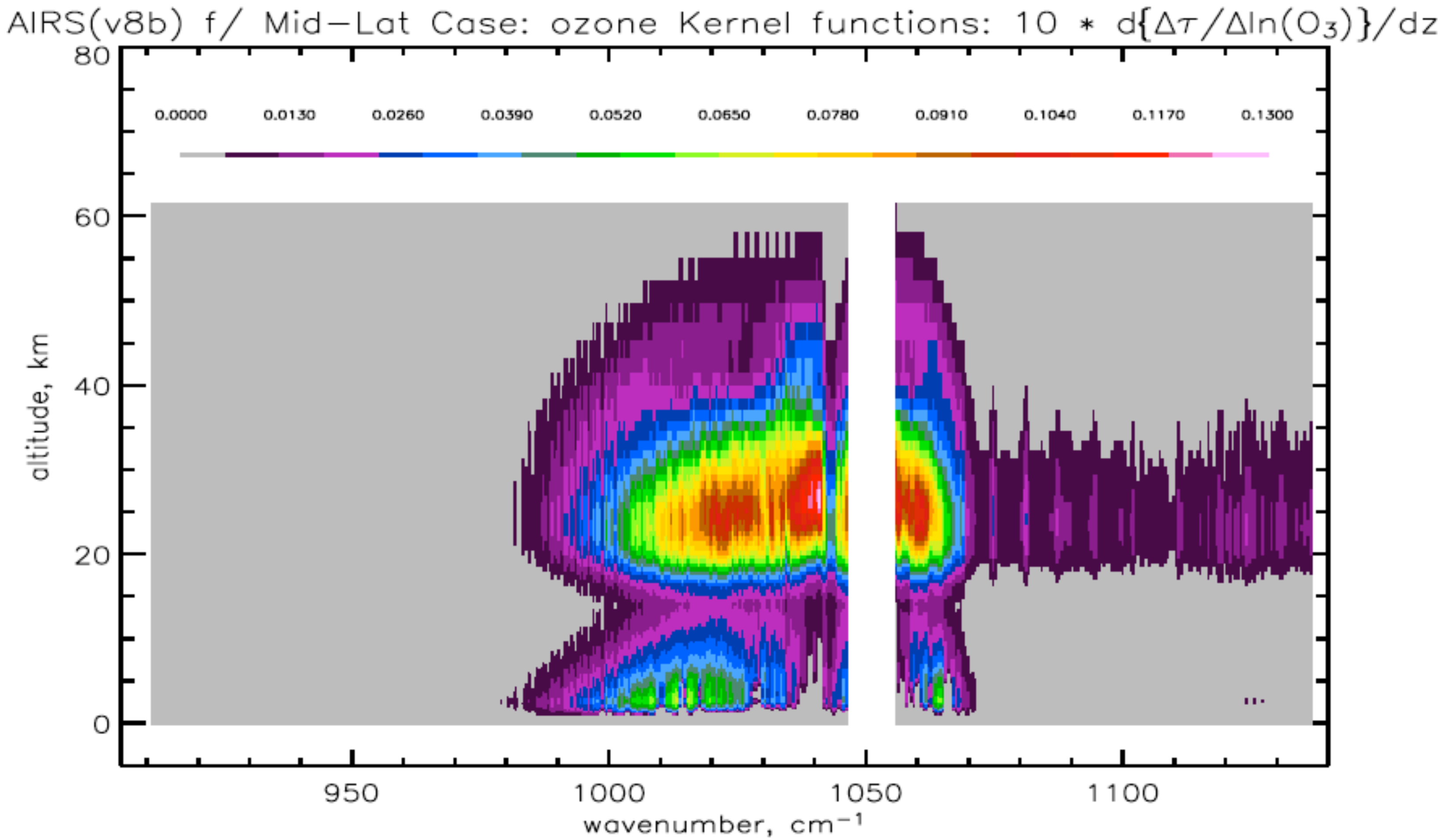
- 8,461 spectral bands in the IR (3.7 – 15.4 μm)
- +/- 48.3 ^{o} swath
- 4 FOV, 50 km horizontal resolution at L2
- Launch: October 2006
- AM Equator-crossing
- Aboard METOP-A (plans for METOP-B in 2010 and METOP-C in 2015)



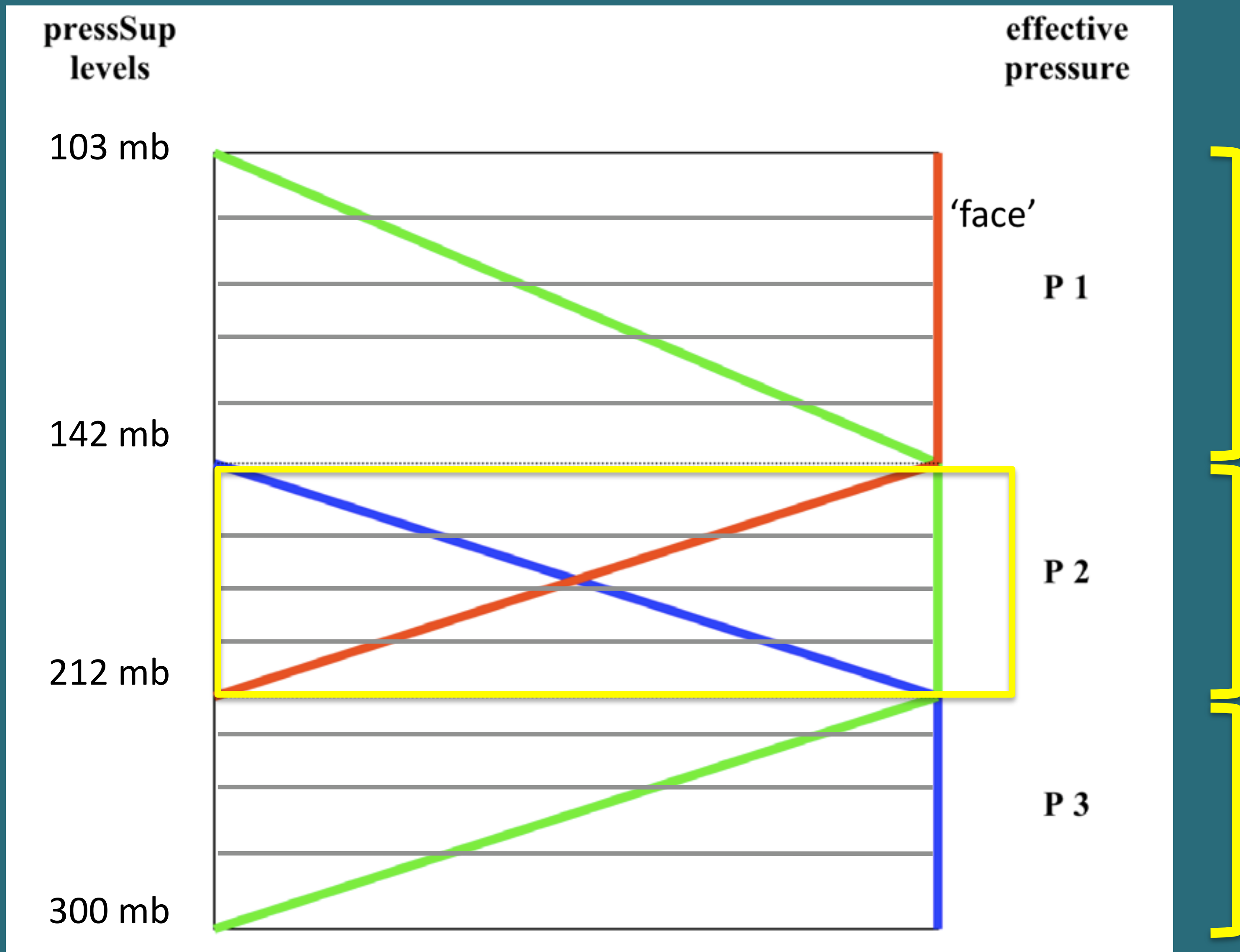
OMI

- UV (270 – 314 nm, 306 – 380 nm) and Visible (350 – 500 nm)
- +/- 57 ^{o} FOV nadir imager
- 3-km IFOV, binned to 13x24 km
- Launch: July 2004
- PM Equator-crossing
- Aboard Aura

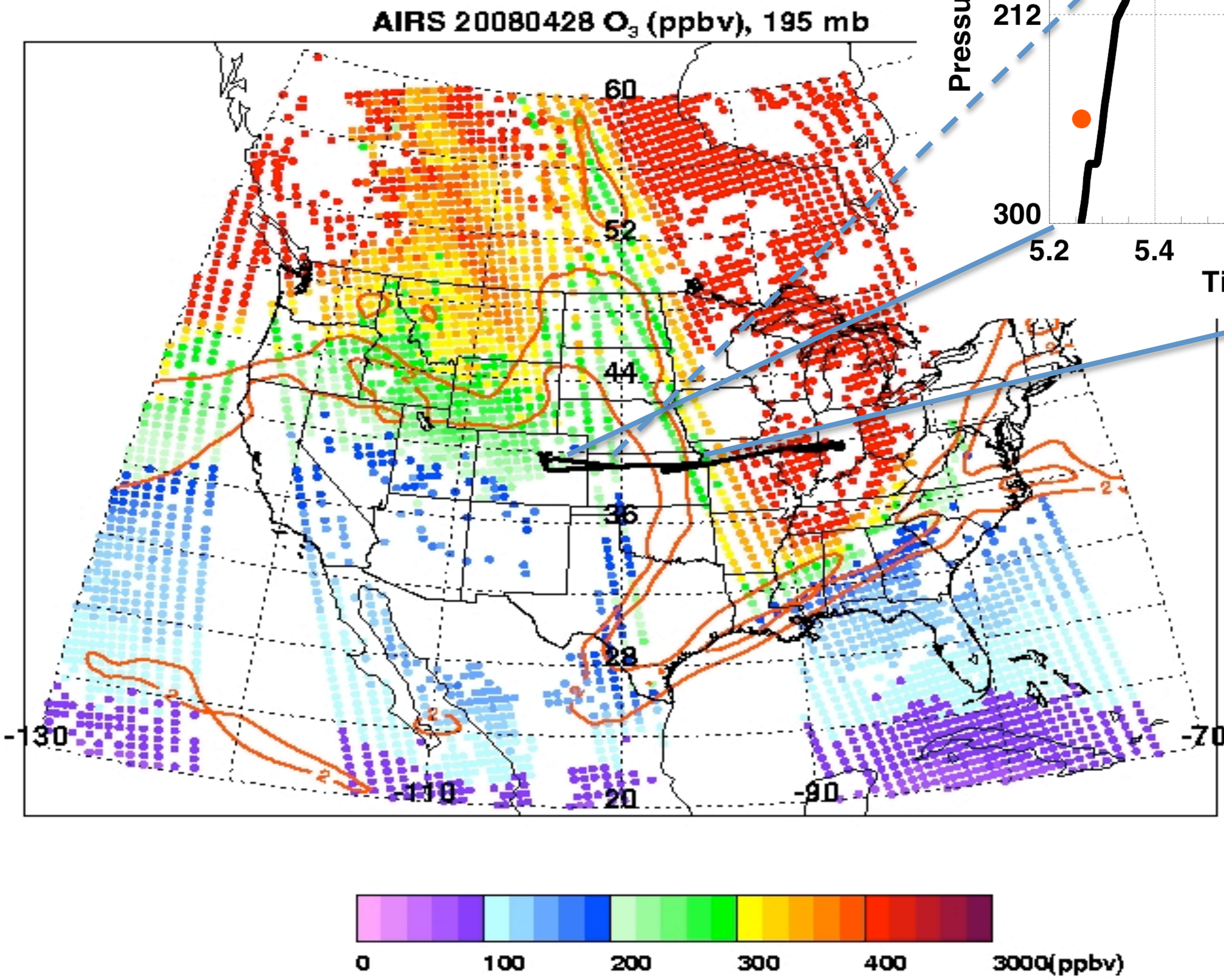
AIRS $O_3(p)$ KERNEL Functions: 910$\rightarrow$ 1140 cm^{-1}

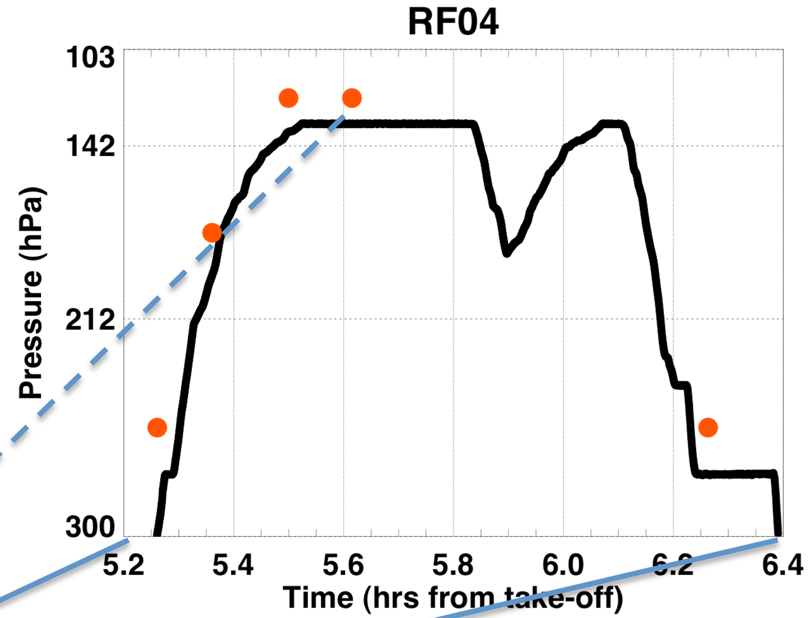


Trapezoids and Pressure-weighted Layer Averages



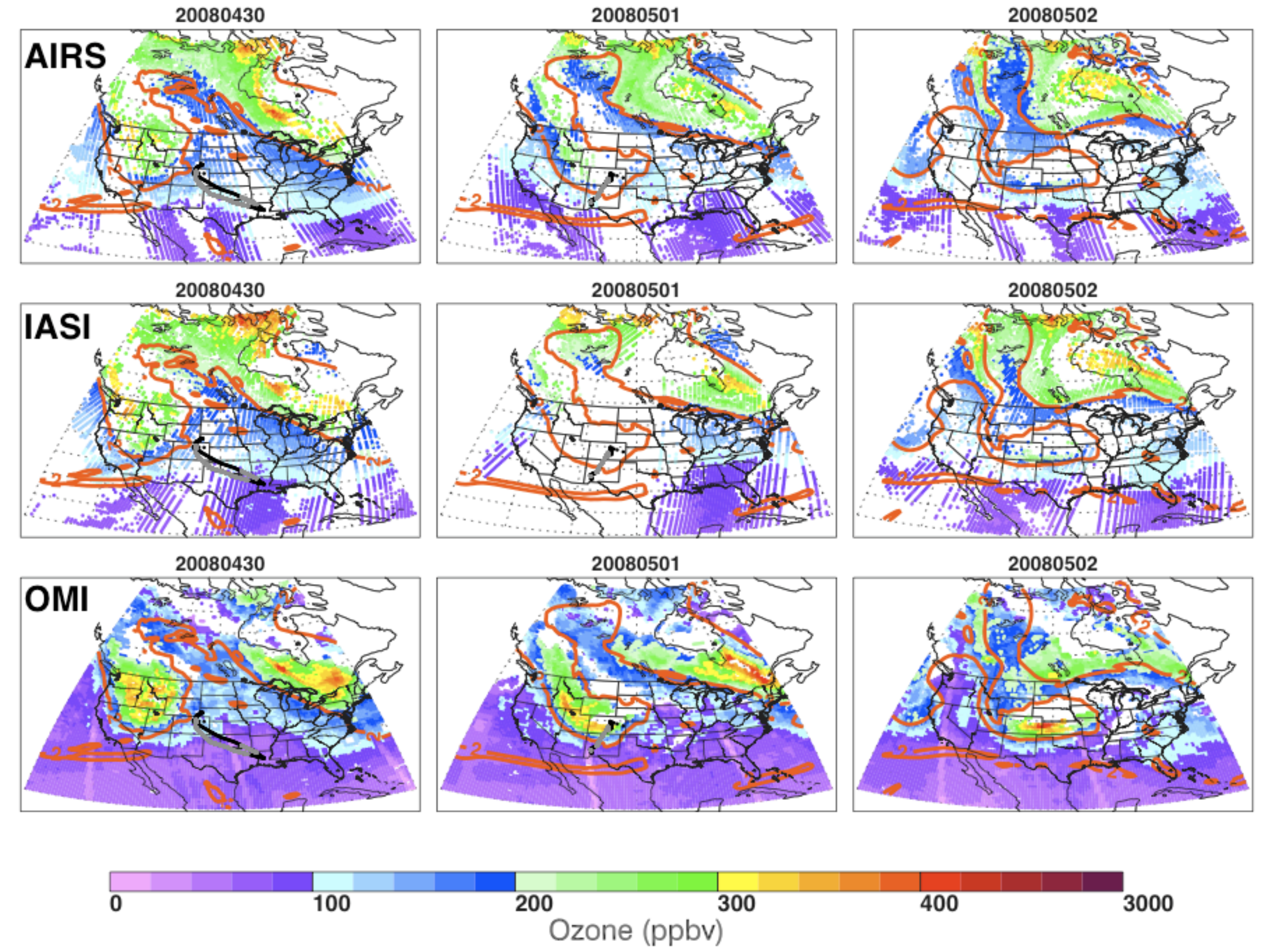
Three Trapezoids in the UTLS region





Dynamic variability

Spatial and Temporal evolution of large-scale Ozone features

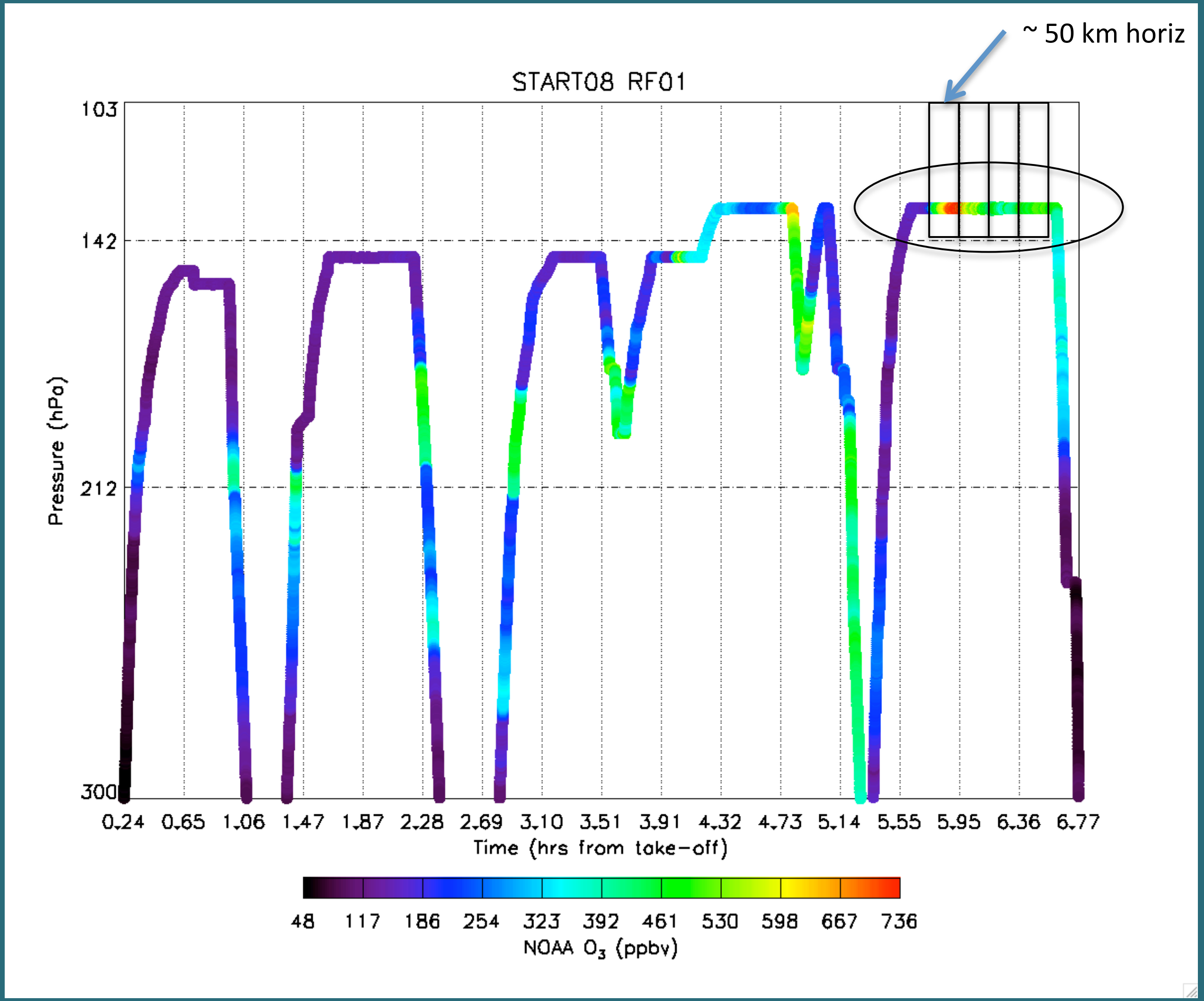


Ozone 212-300-mb; Total Cloud Fraction < 70%

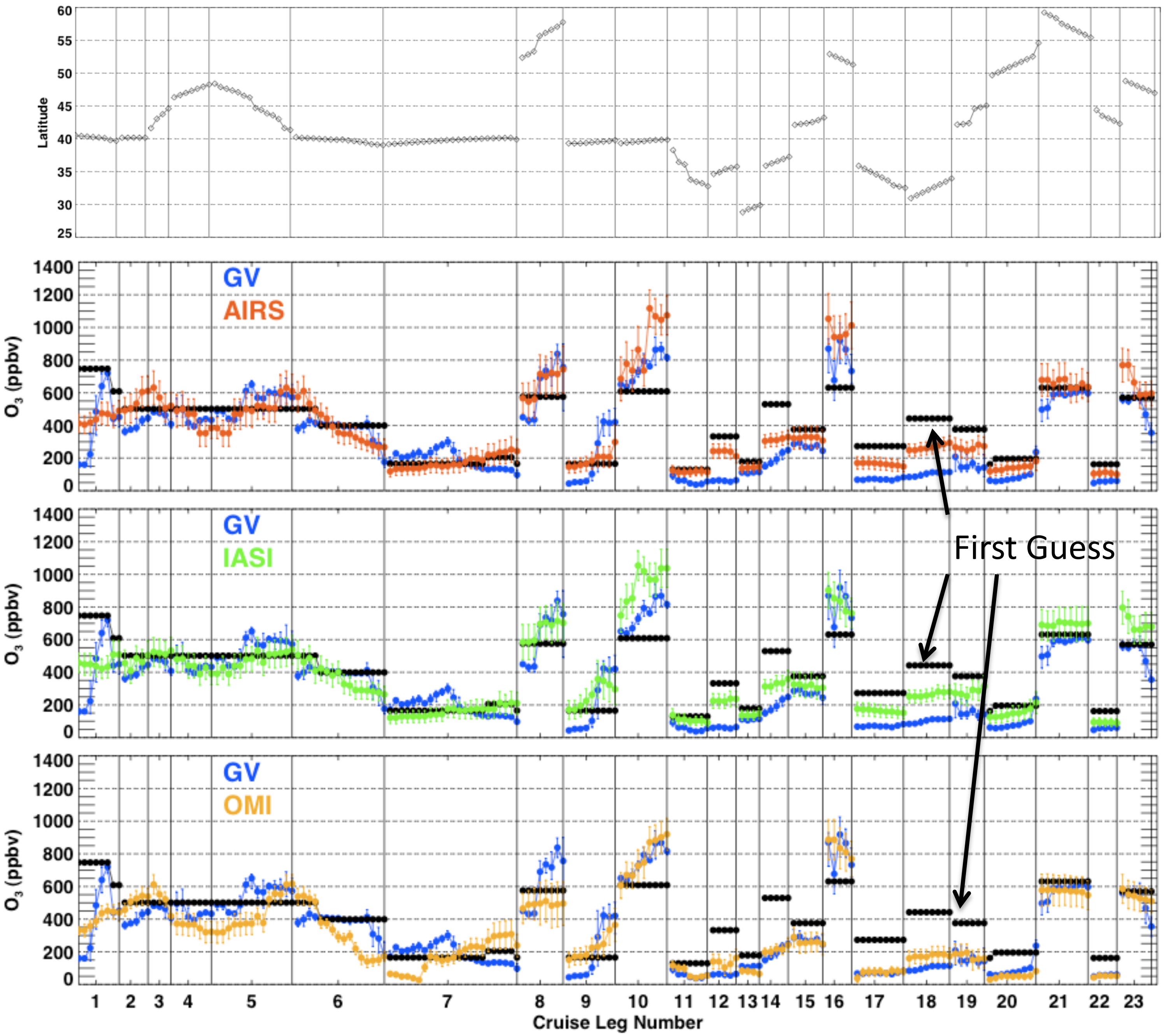
Horizontal variability

1- How well do satellite instruments track horizontal (i.e., ~constant pressure) gradients in Ozone?

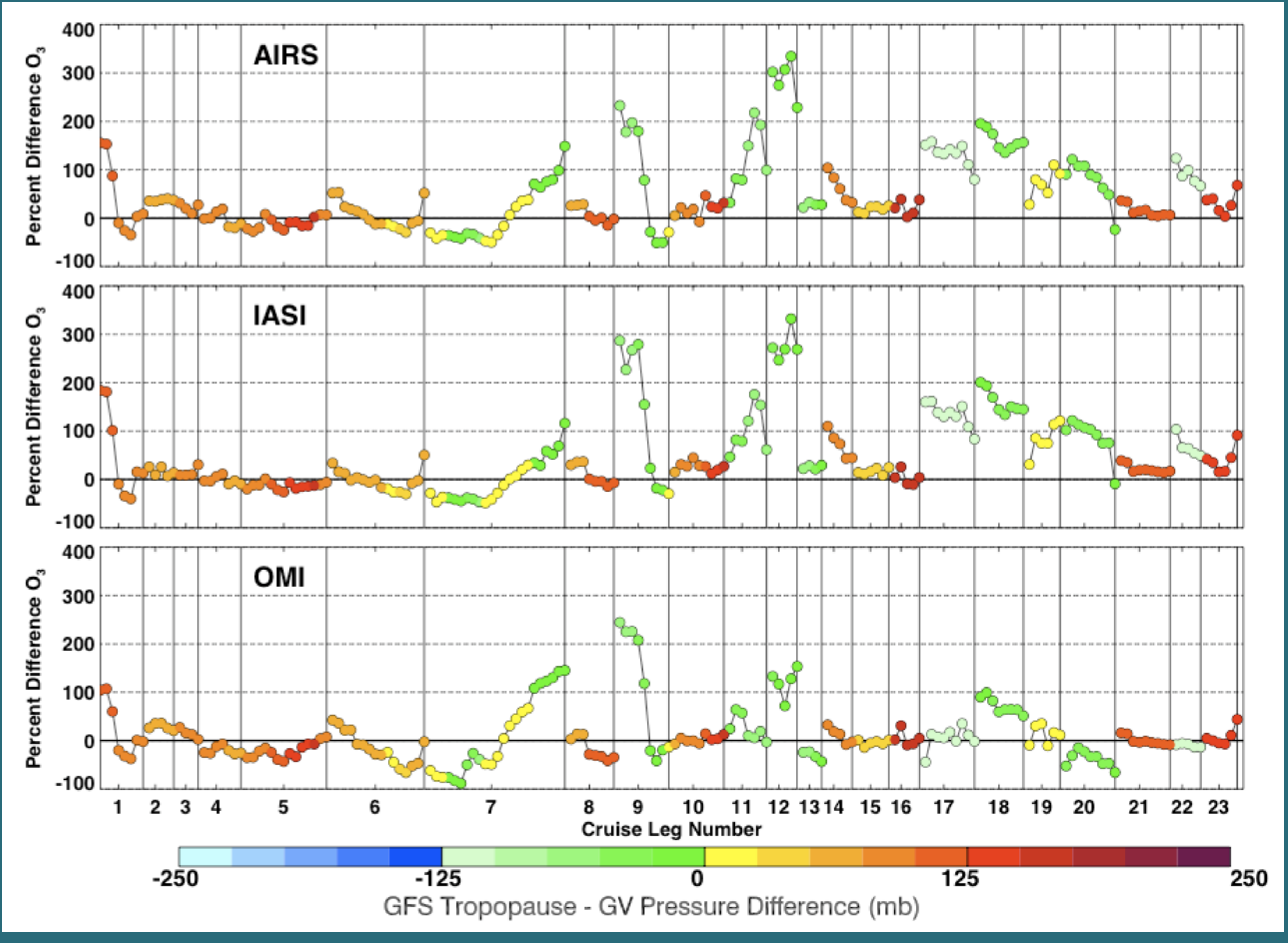
2- How can satellite-aircraft disagreements be explained (e.g., distance to tropopause, cloud fraction, cloud top height, …) ?

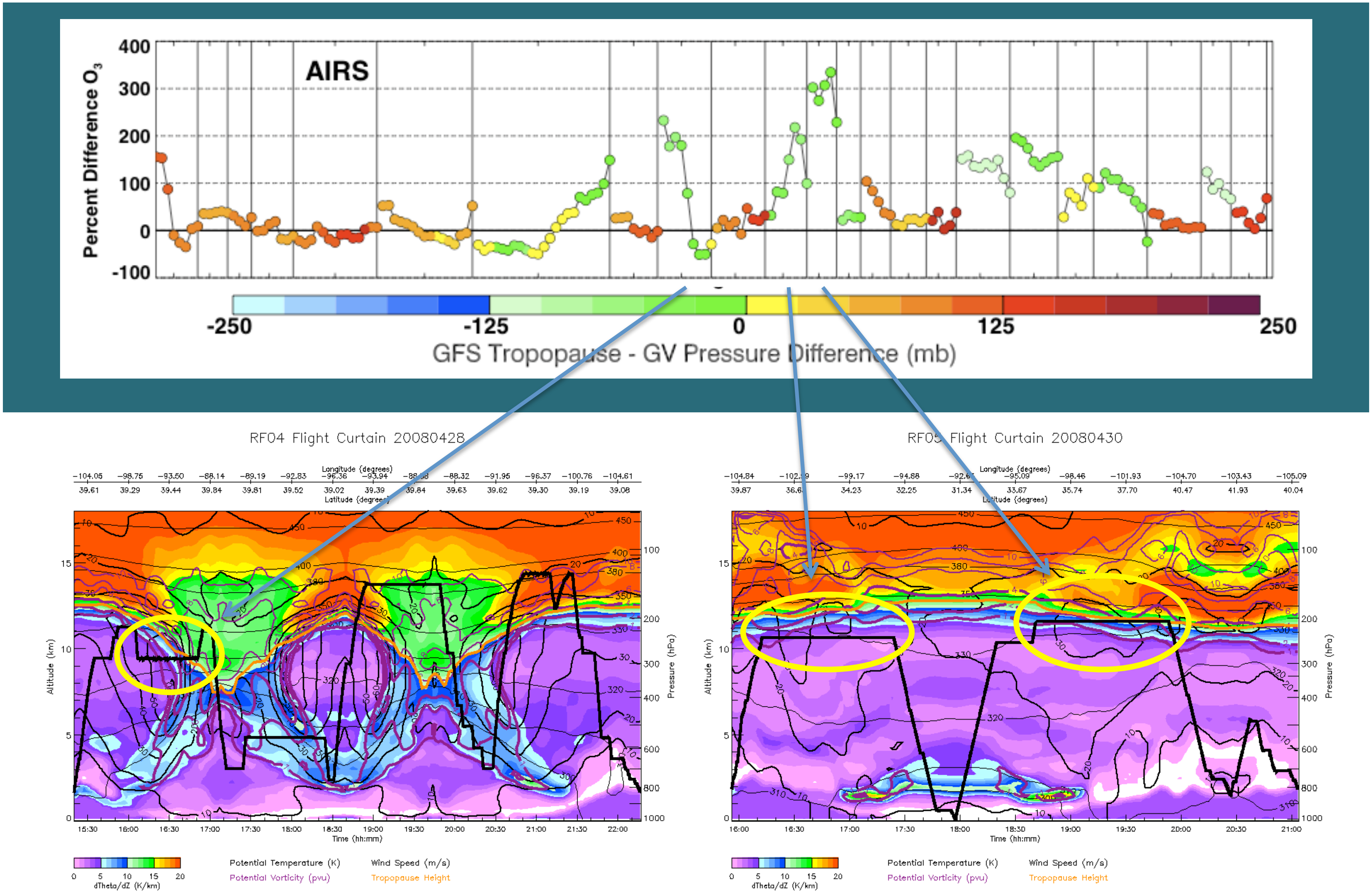

~ 50 km horiz
START08 RF01
103
142
212
300
Pressure (hPa)
0.24 0.65 1.06 1.47 1.87 2.28 2.69 3.10 3.51 3.91 4.32 4.73 5.14 5.55 5.95 6.36 6.77
Time (hrs from take-off)
48 117 186 254 323 392 461 530 598 667 736
NOAA O_3 (ppbv)

23 Cruise Legs (> 200 km each)



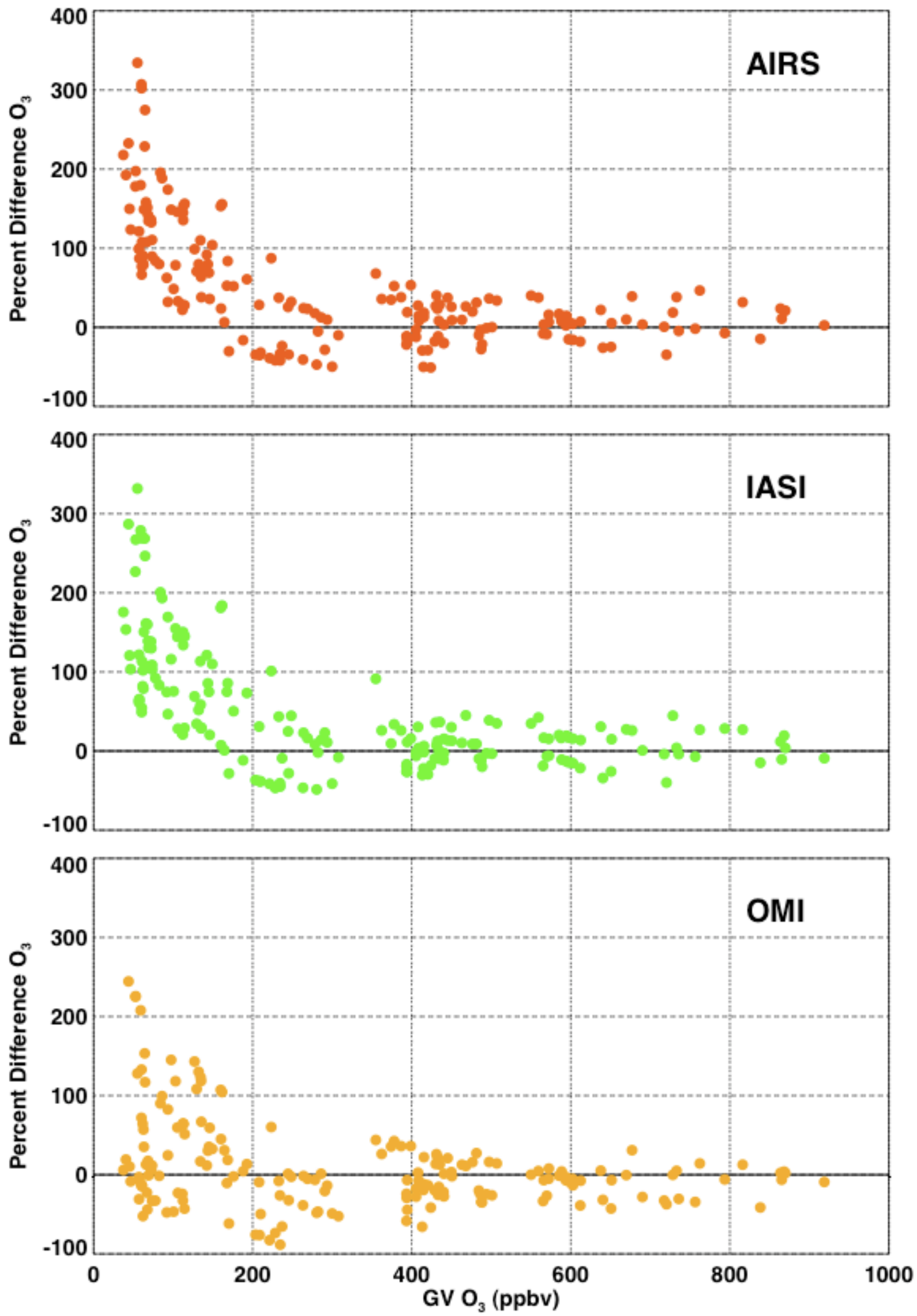
Satellite-Aircraft Dependence on Distance to Thermal Tropopause?



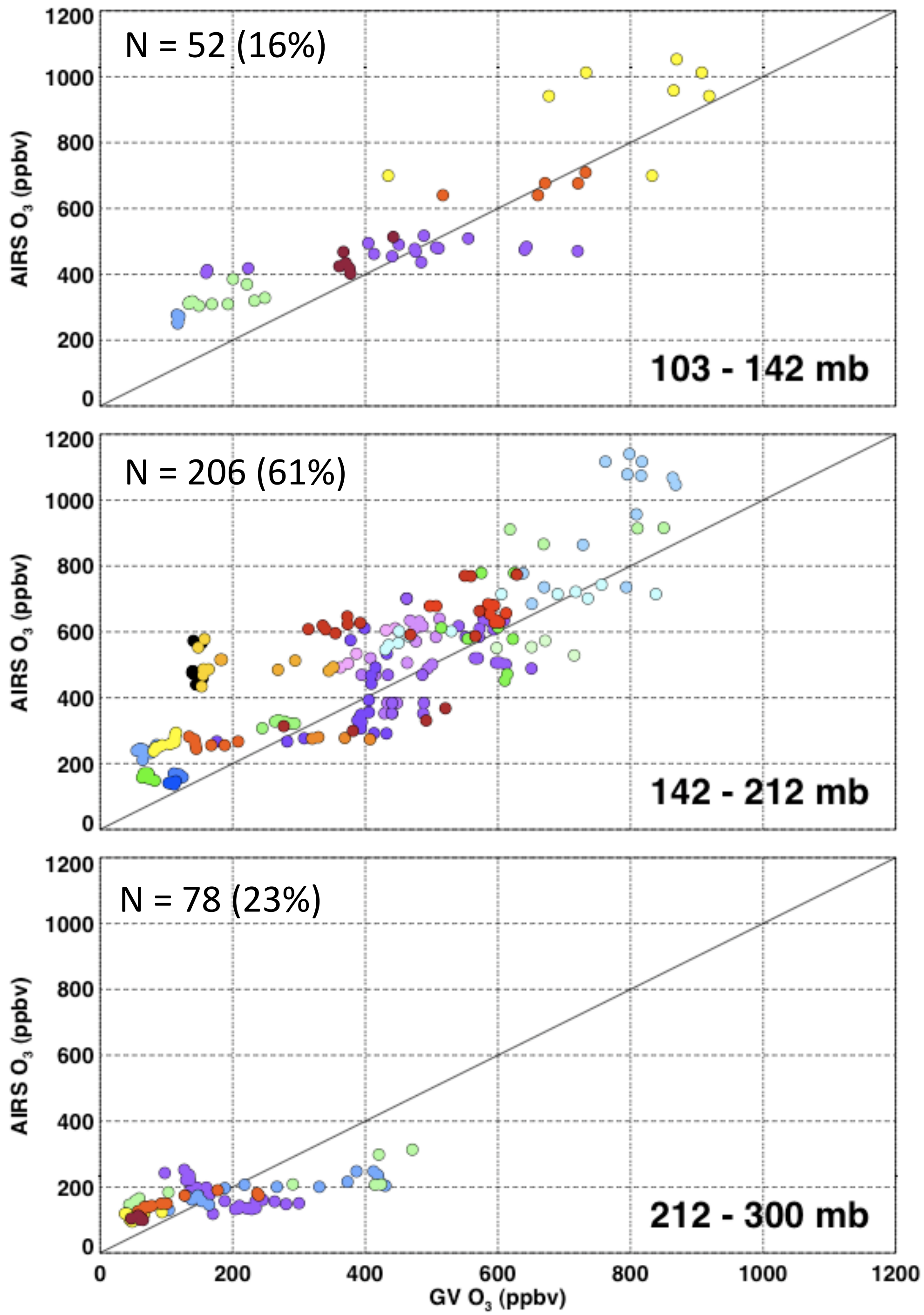


Thermal Tropopause
2 PVU Tropopause

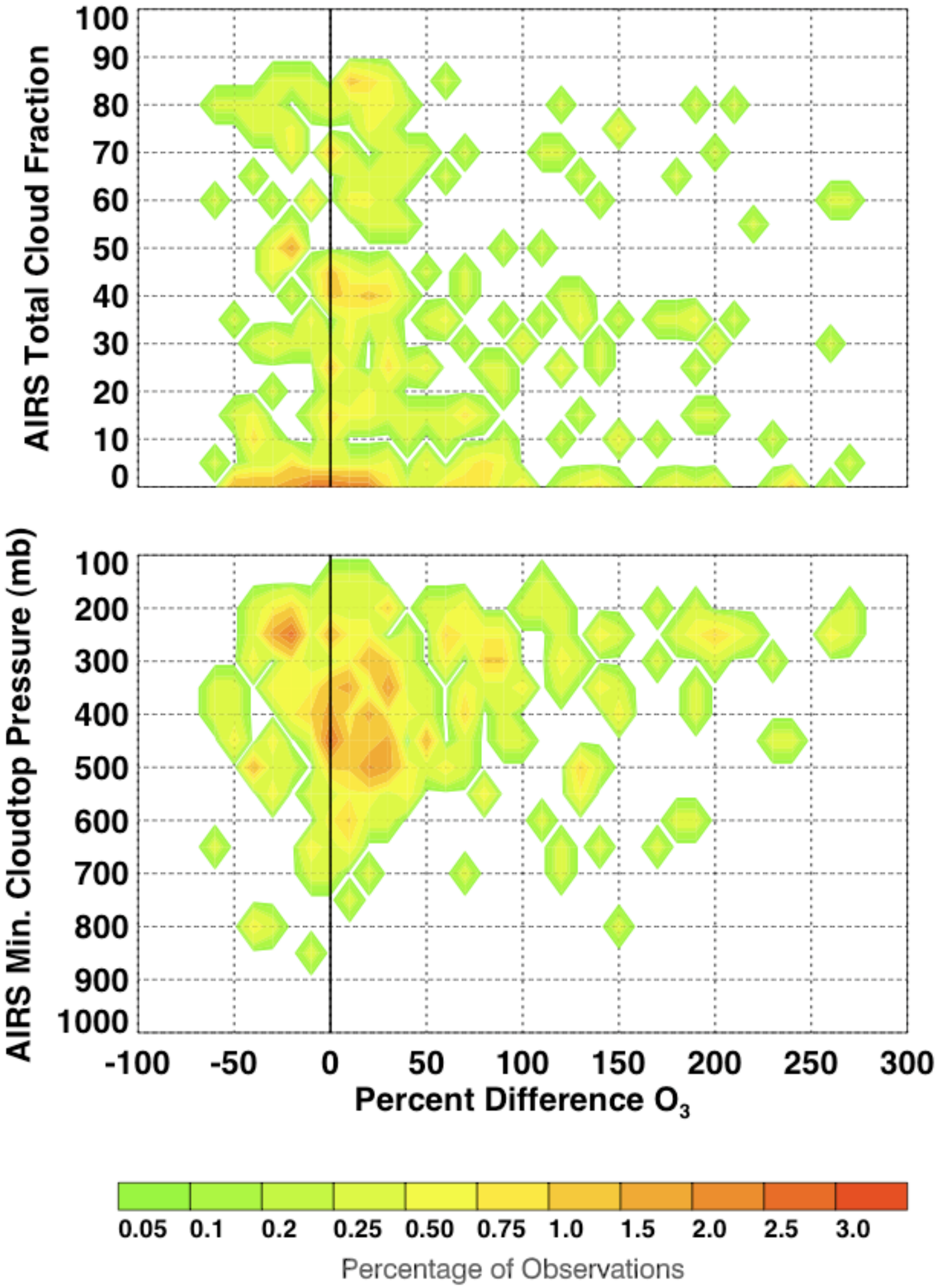
Satellite-Aircraft Dependence on Ozone magnitude?



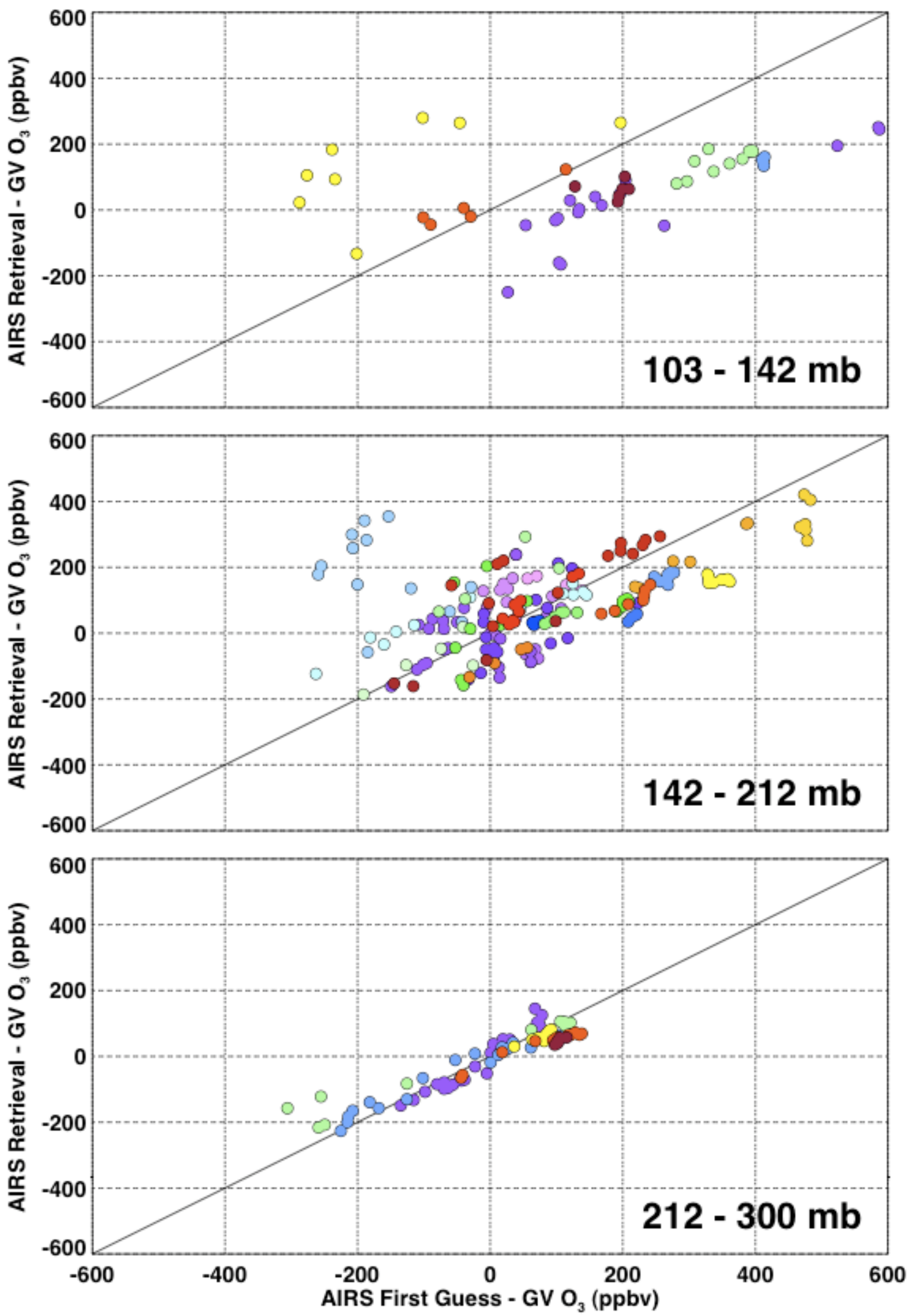
AIRS only compared to GV aircraft



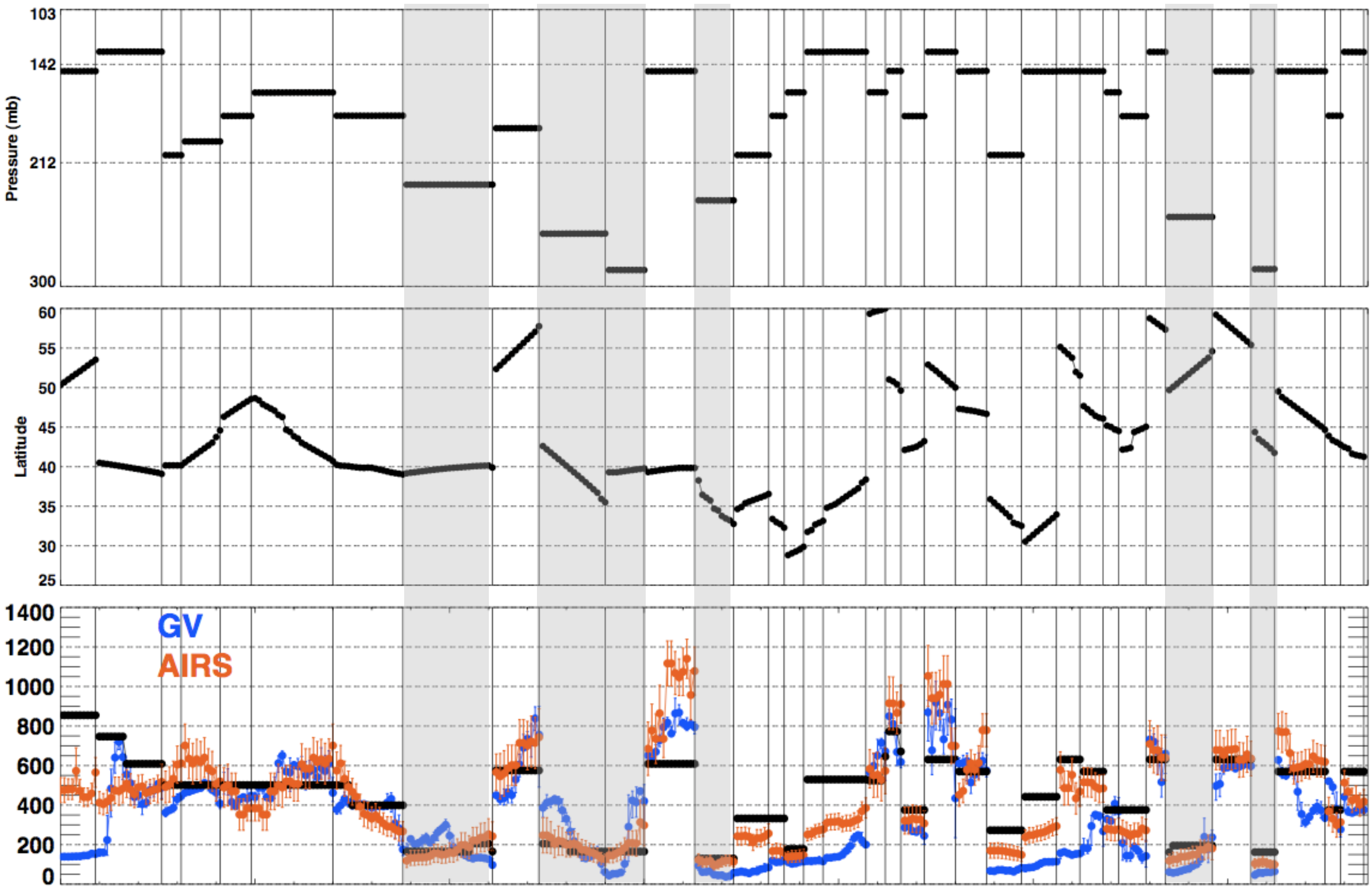
AIRS-Aircraft Dependence:
on Cloud Fraction?
On Cloudtop Pressure?



AIRS First Guess versus AIRS Retrieval

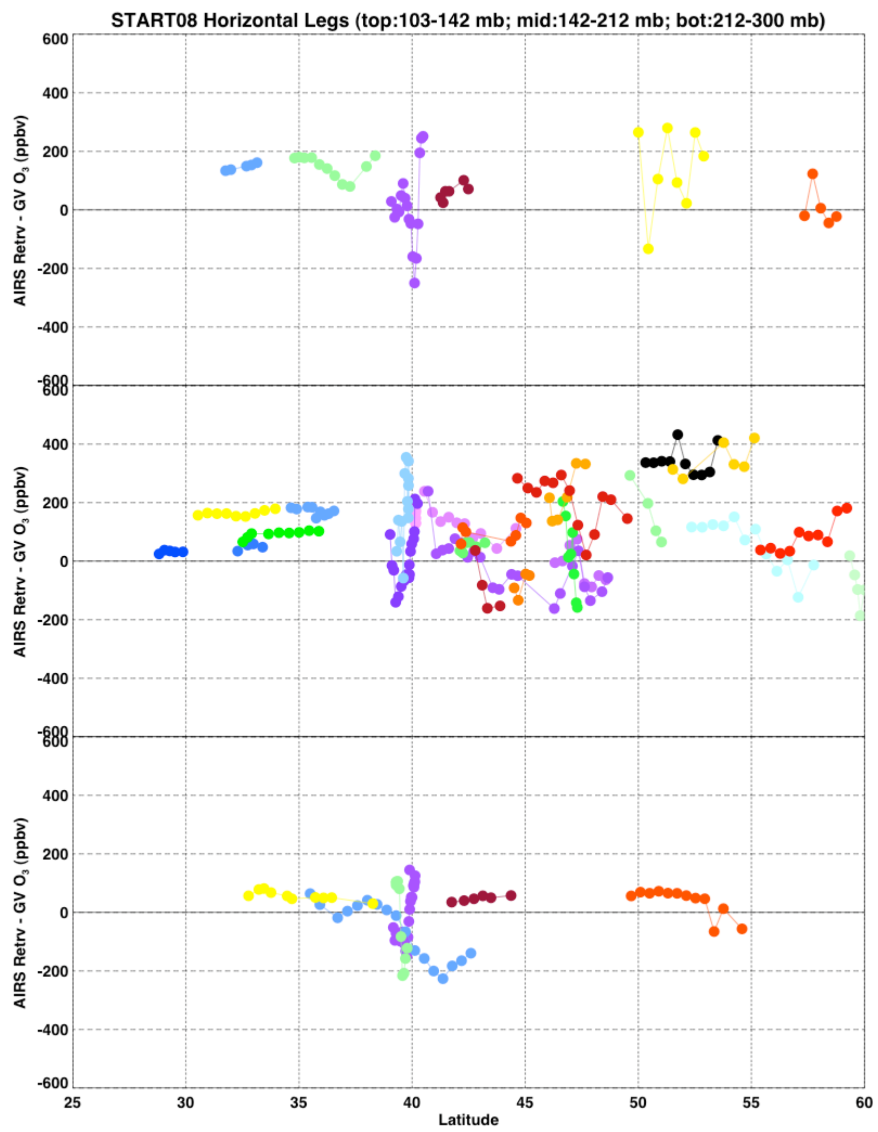


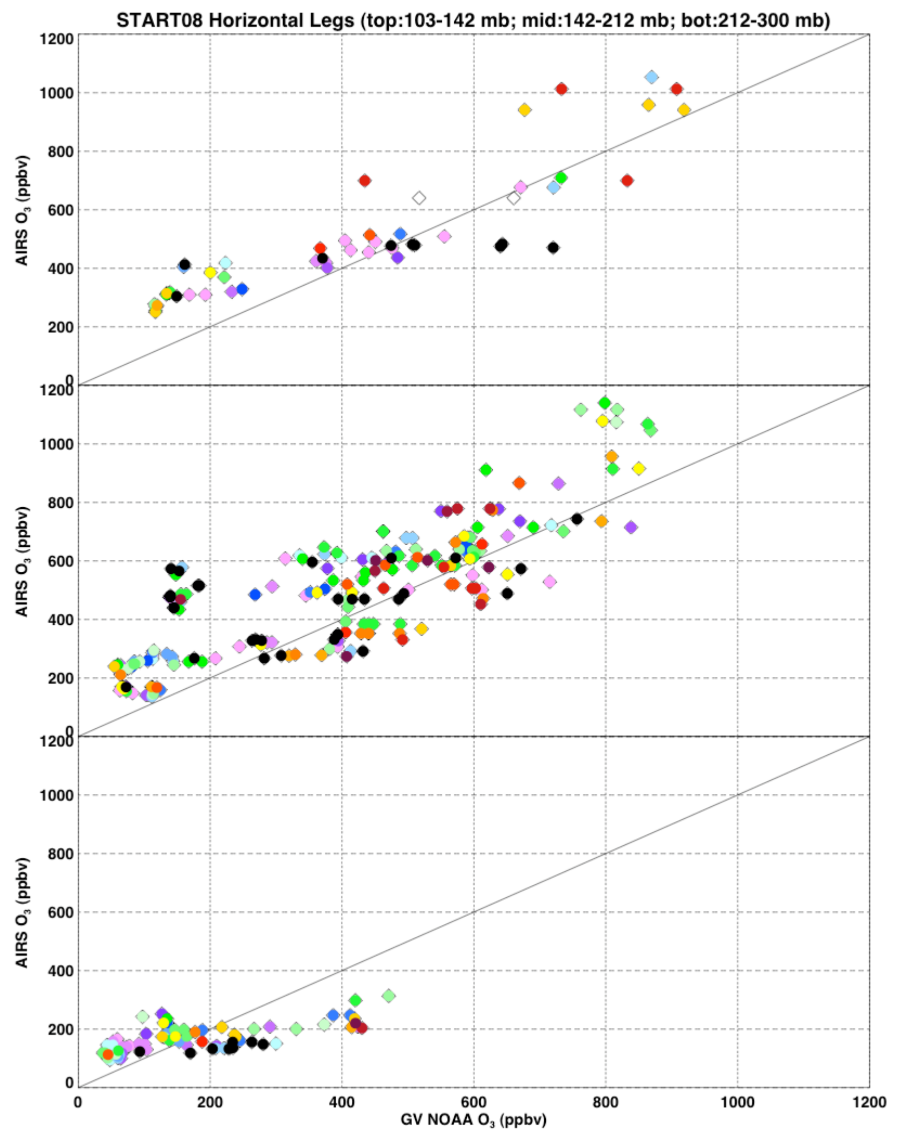
36 Cruise Legs (> 200 km each)



Percent Difference versus Latitude

AIRS and aircraft colored by Cloud Contrast

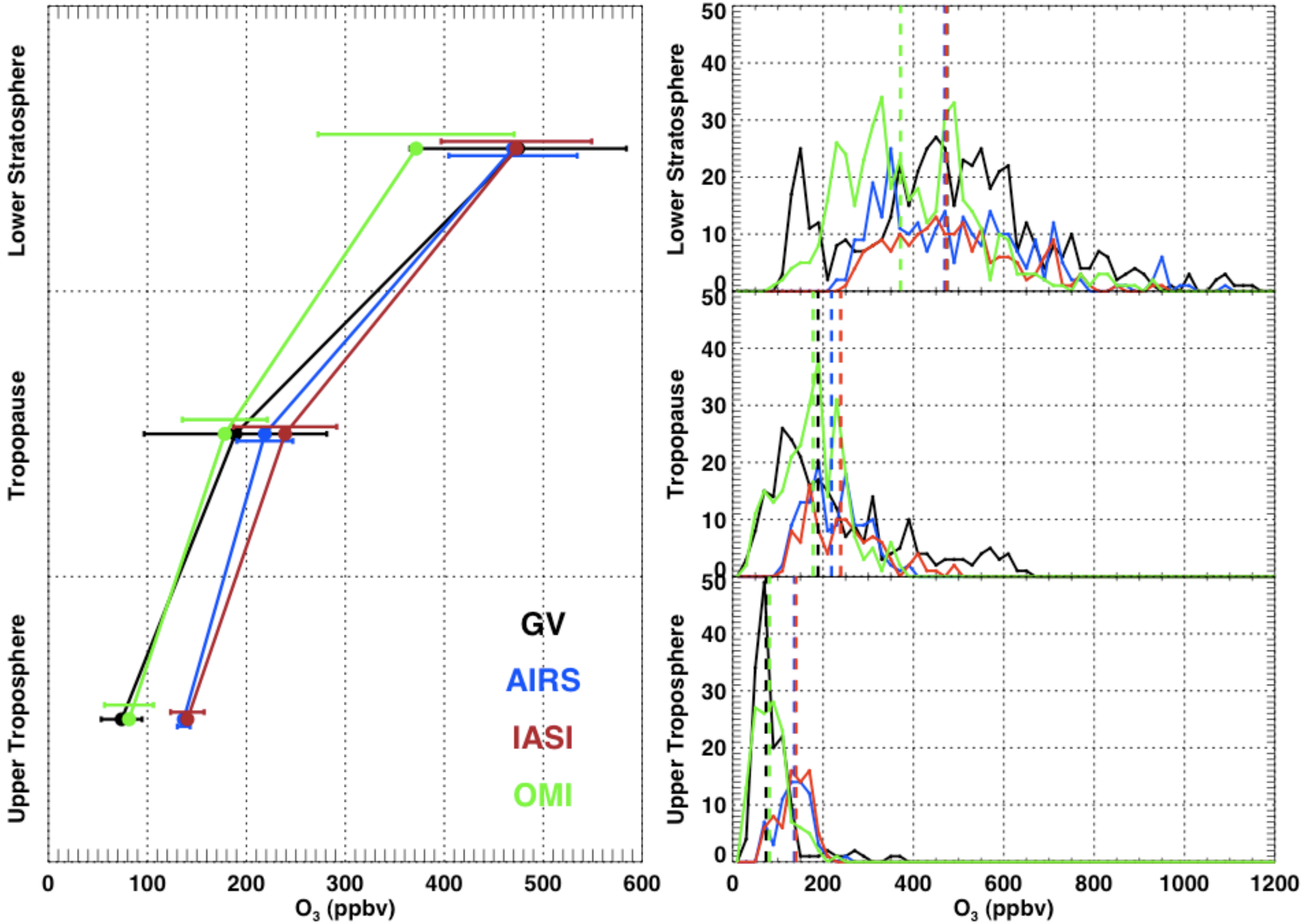




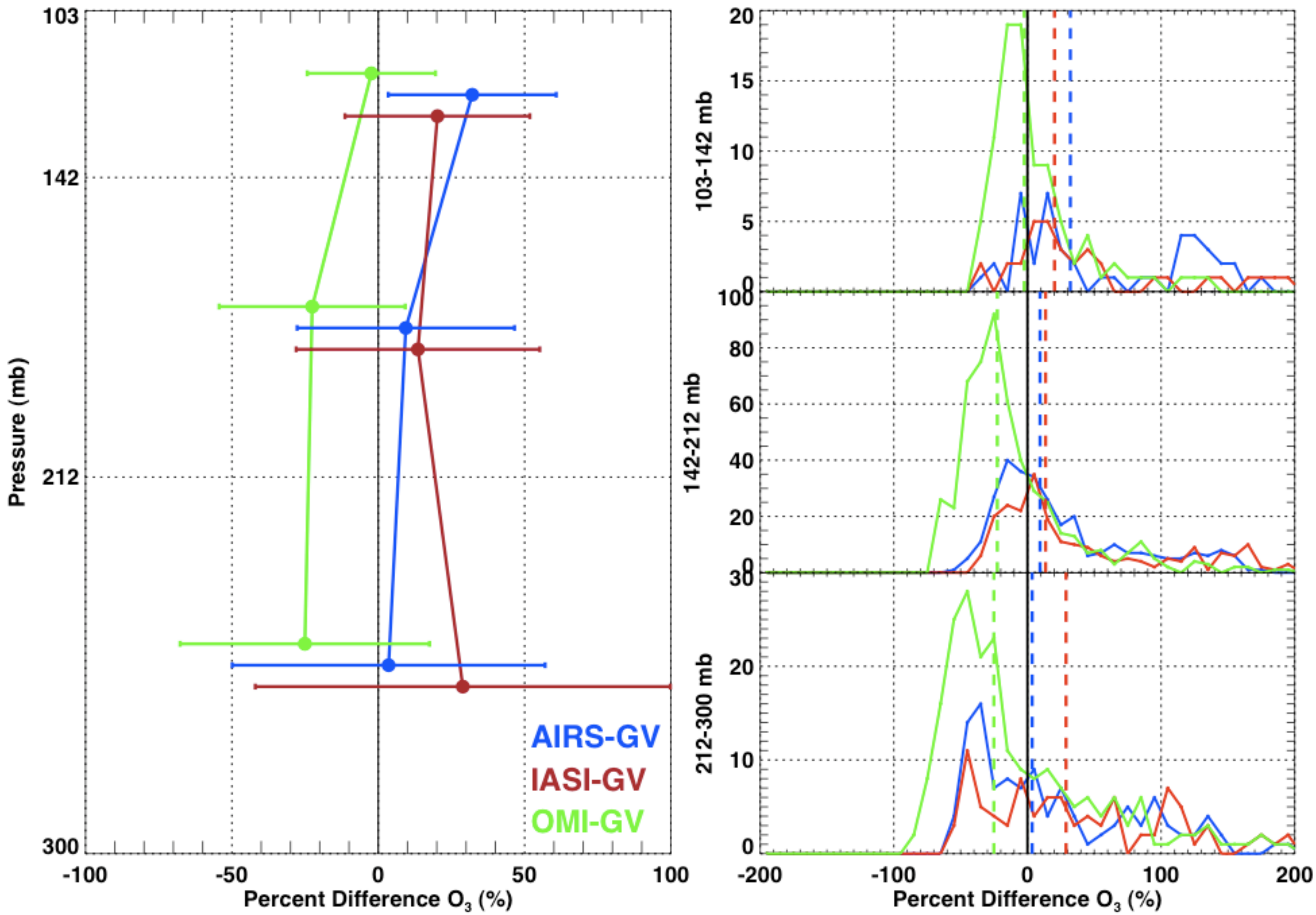
Vertical variability

1- How well do satellite instruments capture Troposphere-to-Stratosphere transition (i.e., slope) in Ozone?

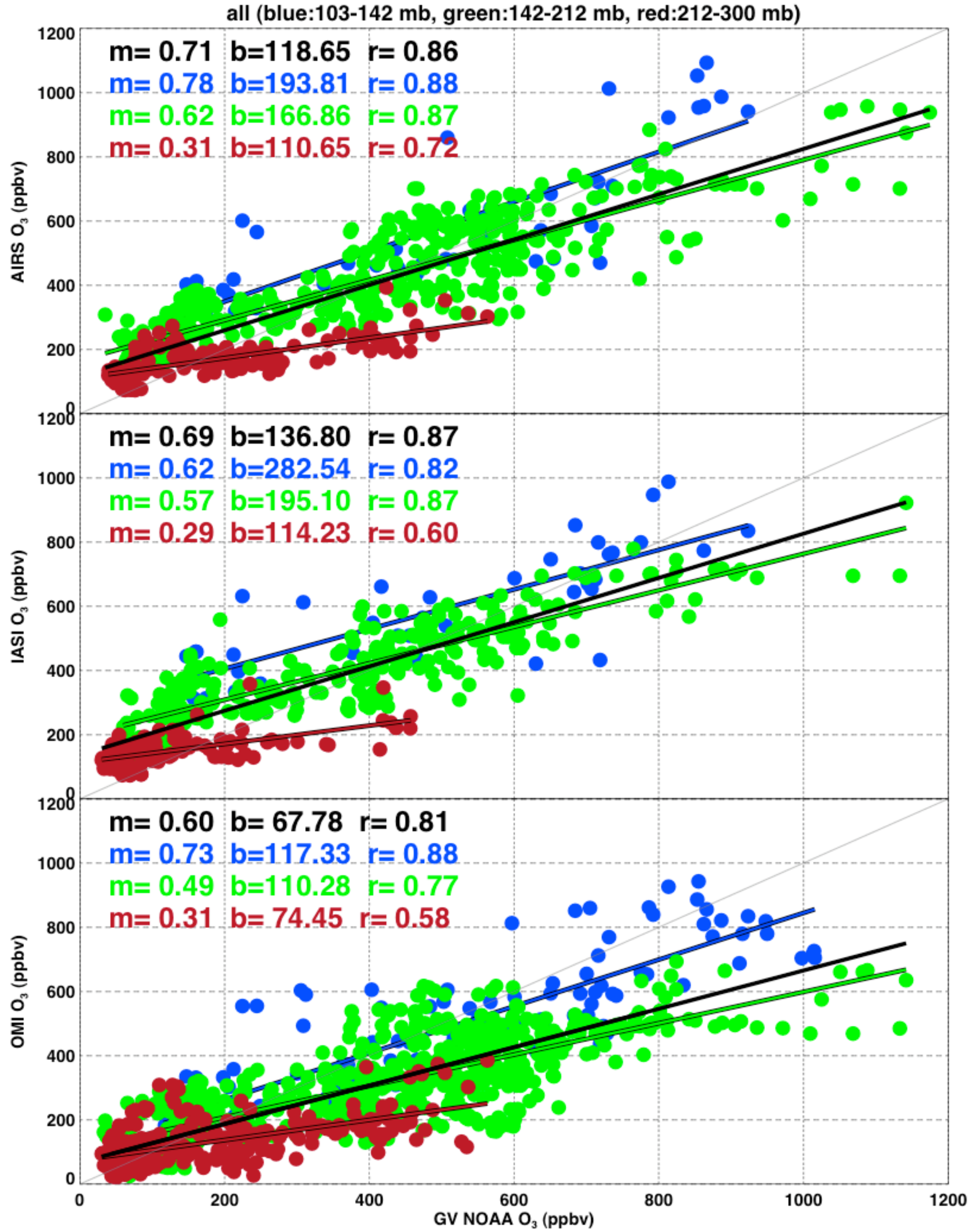
2- How well do satellite instruments agree with GV Ozone magnitudes as a function of height?



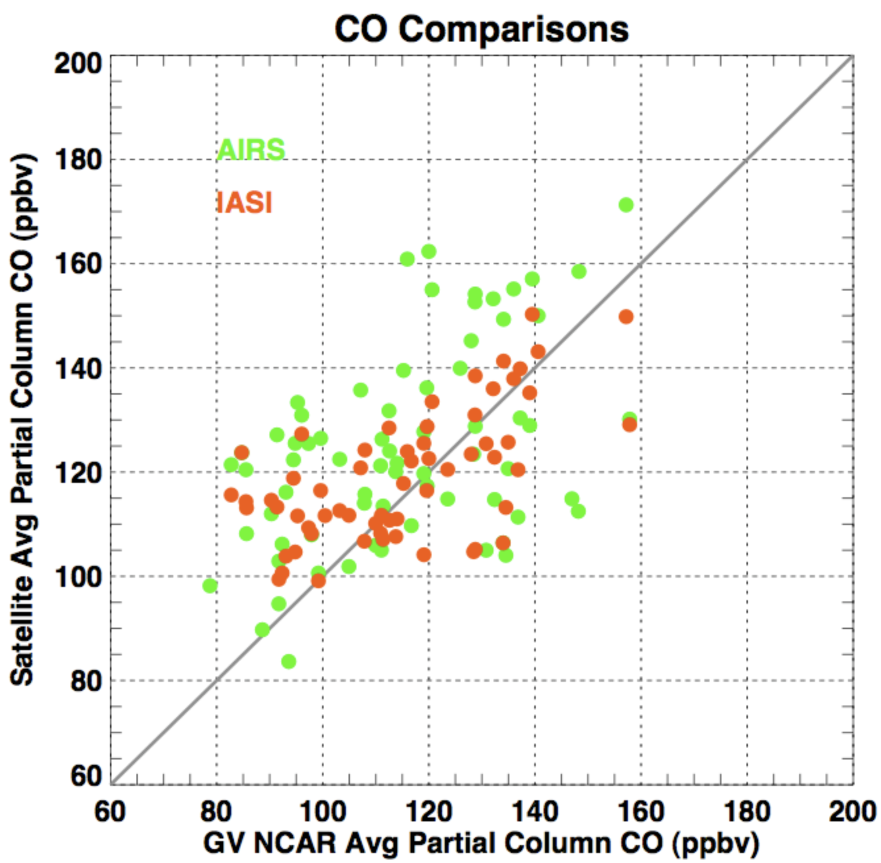
Lower Stratosphere
Tropopause
Upper Troposphere
GV
AIRS
IASI
OMI
0
100
200
300
400
500
600
O3 (ppbv)
50
40
30
20
10
0
200
400
600
800
1000
1200

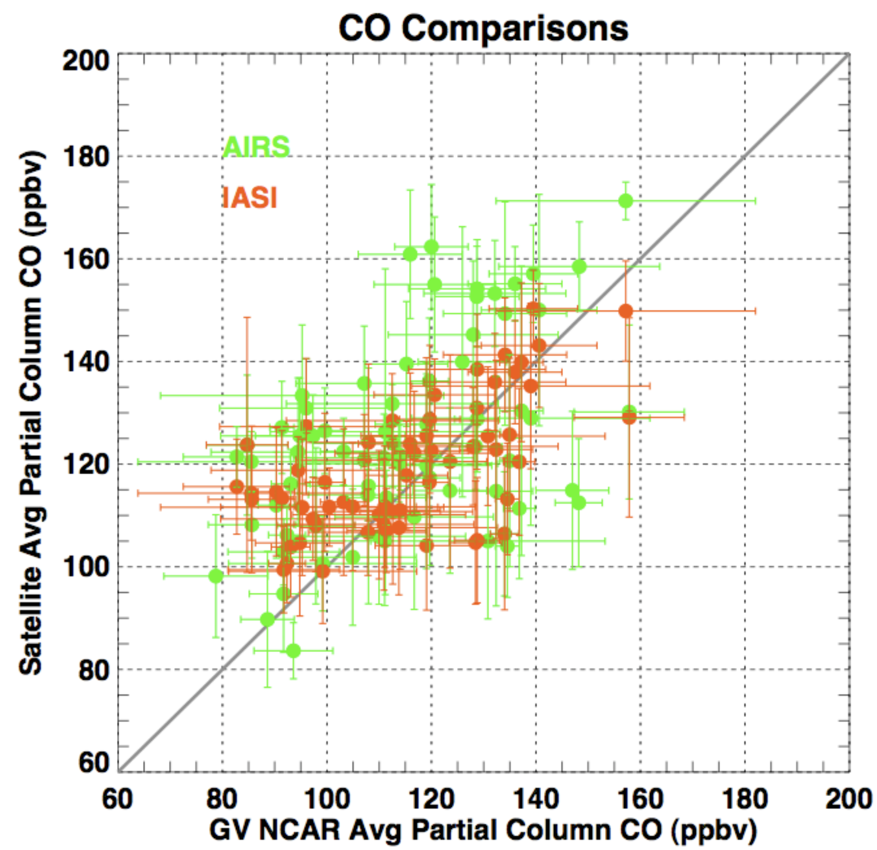


103
142
212
300
Pressure (mb)
-100
-50
0
50
100
Percent Difference O_3 (%)
AIRS-GV
IASI-GV
OMI-GV
103-142 mb
142-212 mb
212-300 mb
-200
-100
0
100
200


all (blue:103-142 mb, green:142-212 mb, red:212-300 mb)
m= 0.71 b=118.65 r= 0.86
m= 0.78 b=193.81 r= 0.88
m= 0.62 b=166.86 r= 0.87
m= 0.31 b=110.65 r= 0.72
AIRS O3 (ppbv)
m= 0.69 b=136.80 r= 0.87
m= 0.62 b=282.54 r= 0.82
m= 0.57 b=195.10 r= 0.87
m= 0.29 b=114.23 r= 0.60
IASI O3 (ppbv)
m= 0.60 b= 67.78 r= 0.81
m= 0.73 b=117.33 r= 0.88
m= 0.49 b=110.28 r= 0.77
m= 0.31 b= 74.45 r= 0.58
OMI O3 (ppbv)
0 200 400 600 800 1000 1200
GV NOAA O3 (ppbv)

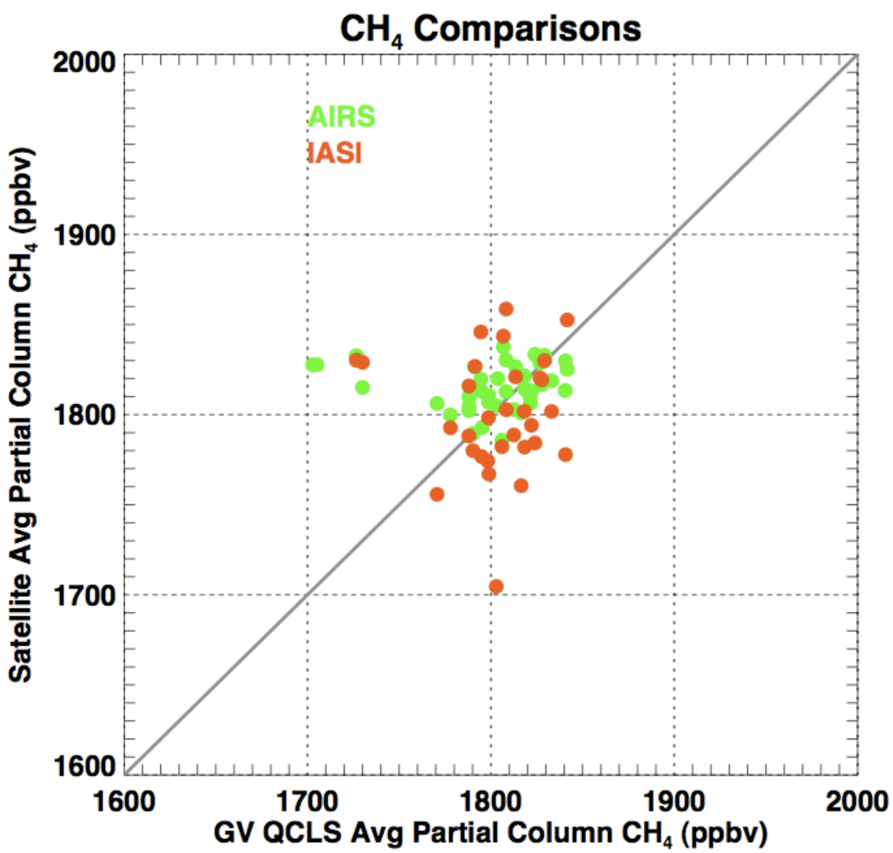
Partial Column Comparisons of CO_2, CO, and CH_4

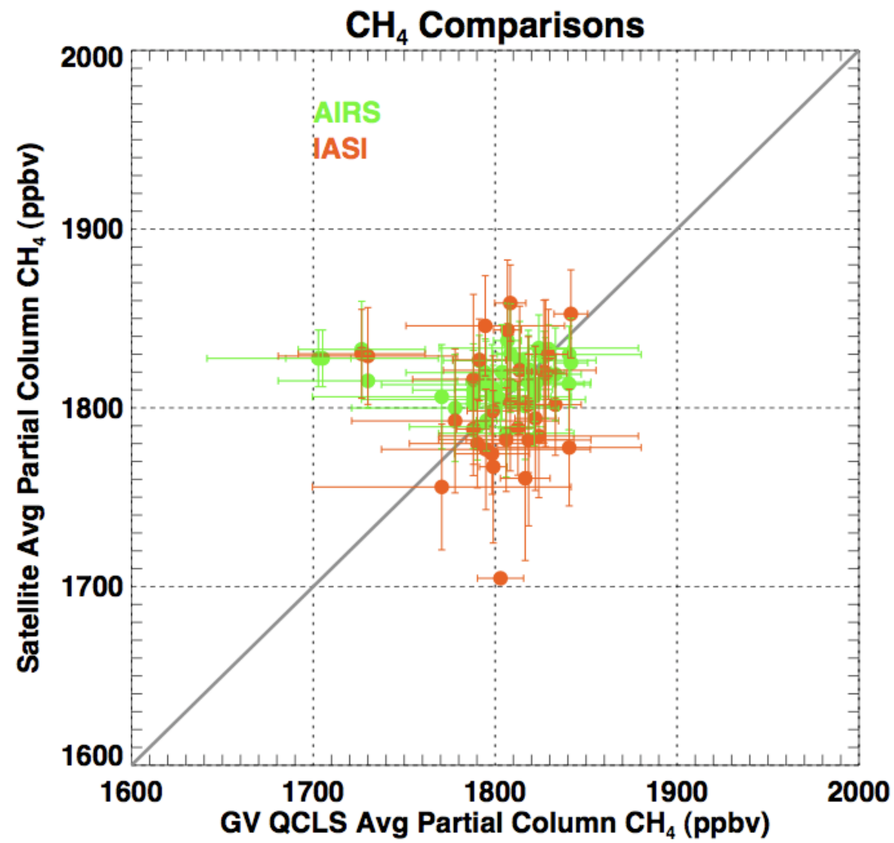




# of columns (finite GV NCAR and AIRS) = 69;   # of columns (finite GV NCAR and IASI) = 61

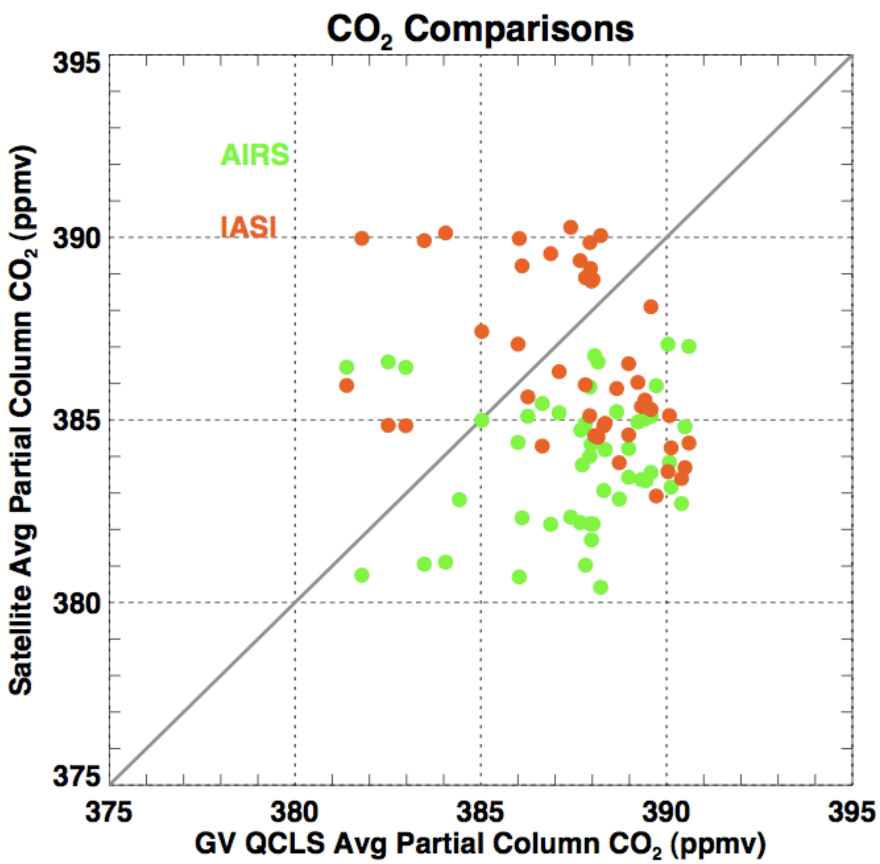
Satellite goes out to +/-200 km from center of GV profile
Can't constrain time, so satellite 'pixels' can be from different orbits

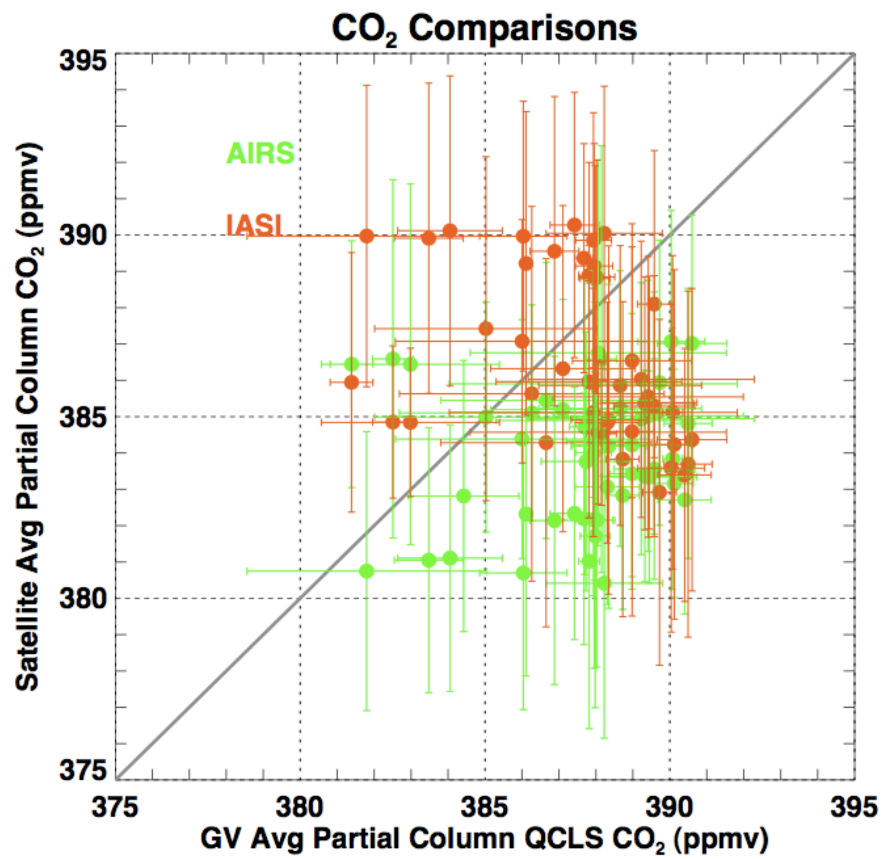




# of columns (finite GV QCLS and AIRS) = 39; # of columns (finite GV QCLS and IASI) = 31

Satellite goes out to +/-200 km from center of GV profile
Can't constrain time, so satellite 'pixels' can be from different orbits





# of columns (finite GV QCLS and AIRS) = 49; # of columns (finite GV QCLS and IASI) = 45

Satellite goes out to +/-750 km from center of GV profile
Require at least 100 L2 satellite ‘pixels’
Can’t constrain time, so satellite ‘pixels’ can be from different orbits

Conclusions

- AIRS/IASI/OMI Ozone show strong correlations with PV contours in space and time.
- All 3 satellite instruments show a consistent behavior (qualitatively and quantitatively) despite different measurement techniques and time of measurement when compared to the in situ observations.
- AIRS/IASI/OMI show a good qualitative agreement with the aircraft in the presence of horizontal gradients in Ozone. Quantitative disagreements are correlated with proximity to the thermal tropopause and cloud top pressure (IR meas.), but not with cloud fraction, latitude, or cloud contrast.
- OMI agrees best with the aircraft at the UT and Tropopause, while AIRS and IASI agree best with the aircraft in the LS.
- AIRS and IASI show positive biases in the UTLS within 30% of the aircraft; OMI shows negative biases in the UTLS within 25%, instead.
- IASI CO shows good correlation and less scatter than AIRS; AIRS and IASI CH_4 show opposing behaviors with respect to the aircraft; AIRS ad IASI CO_2 show very weak correlations with respect to the aircraft.